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ABSTRACT

This pamphlet presents the statement of Dr. James C. Fletcher, administrator, National Aeronautics and Space Administration, made before the Committee on Aeronautical and Space Sciences, U. S. Senate. It is an attempt to give some idea of how space and aeronautics will affect mankind in the year 1985. A summary of what has been going on the last 15 years is presented. Aviation's impact on the balance of trade, barriers to aviation growth, and other topics relevant to air travel are discussed. Brief statements are made to incorporate such phenomena as Conquest of Space, Space Shuttle, Space Communications, and Potential of Domestic Satellites. The author attempts to show that NASA, although called the space agency, in a broader sense could be called an environmental agency. (EB)

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SPACESHIP EARTH

a look ahead to a better life

U.S. DEPARTMENT OF HEALTH
EDUCATION & WELFARE
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NATIONAL
AERONAUTICS
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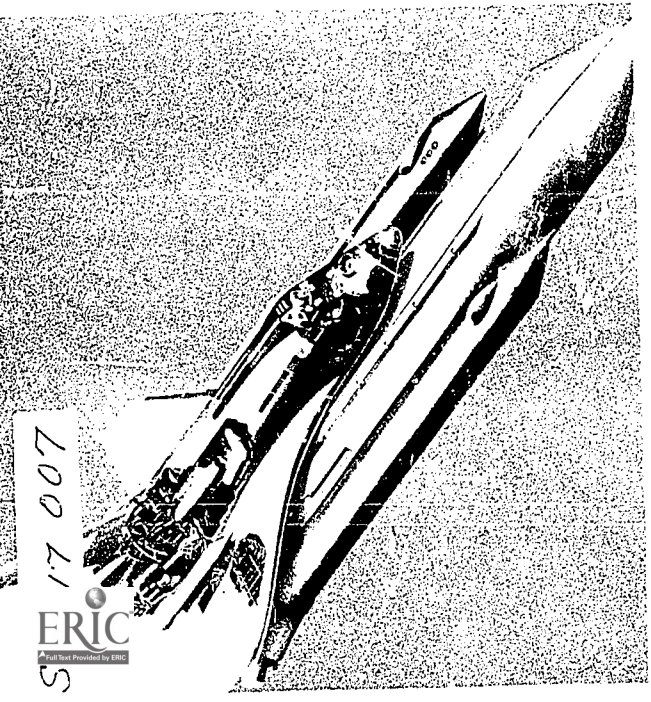

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* Mr. Chairman, Senator Goldwater, this morning we are going to try an experiment with something we have never really attempted before. We are going to try to give a presentation on NASA's long-range objectives, to give a kind of snapshot approach as to what we feel NASA hopes to accomplish in the next 10 to 15 years in light of our 1974 authorization request.

This morning instead of focusing on specific NASA programs or mission models we will instead focus on the impact of these programs to attempt to predict some of the benefits from the space and aeronautics programs which will be realized in the next 10 to 15 years. We will try to give you some idea of how space and aeronautics will affect you and me and all Americans and, to a degree, people throughout the world, in the year 1985.

I think a word ought to be said about forecasting the future, though, and particularly a word ought to be said about scientists. I have been a scientist all my life in a sense, because that is how I was trained. Scientists have some defects, and you are familiar with most of them. But one of the defects is that scientists tend constantly to overestimate what they can do today and underestimate what they can do tomorrow; they just do not look ahead very well into the future. And I think that is proper, because scientists have to be objective. They have to be able to prove their points, and that is part of their training. Projecting the future does involve some risks, particularly in the economic and political arena. So scientists generally underestimate.

On the other hand, it has been my experience, and there are some case histories which show, that hard-nosed, practical businessmen are best able to predict the future, because their livelihood depends on it. If a business cannot project accurately several years ahead, it just

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* Statement of Dr. James C. Fletcher, Administrator, National Aeronautics and Space Administration, before the Committee on Aeronautical and Space Sciences, U.S. Washington, D. C. March 6, 1973.

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is not going to survive. It has to know what the environment is going to be that far ahead. And some of the businessmen, the ones that make the big investments, are the ones that can project the farthest ahead.

So this morning, I am going to try to make use of my business background. I did spend 15 years in private industry and six of those was as chief executive of a private corporation in California.

I hope to be more accurate than the usual scientist. We will see.

Most of what is going to be said this morning cannot be proven, and much of it will not even take place. On the other hand, many other things will take place which we will not discuss and I hope that the broad-brush snapshot treatment that we are going to present will be reasonably accurate. We can look at today's technology, and even though we cannot predict political and economic things, we can make reasonable overall assessments of the future.

Now, one other point I think should be made before we start. That is, what is going to be presented is not dependent solely on NASA programs or even on NASA spinoffs, but will depend on developments in the political and economic arenas as well. I think that we ought to recognize that NASA's program is focused primarily on R. & D. We are not an operational agency. So most of the things that you will see will be operated by other agencies—Government agencies in many cases, private industry in some other cases, or in still some other cases, by international organizations. So I hope this does not compromise your interest in the program. What I am going to show you will be the result of what NASA is doing today and will not be NASA's programs in 1985. Now, with this as an introduction, I would like to begin my presentation.

Fifteen Years Ago Versus Today

First, the best way to predict the future and feel for what 15 years from now will be

like is to take a look at what was going on 15 years ago.

It was just 15 years ago last month [February 1958] that the first U.S. satellite was placed in orbit and there was great concern about the fact that we were second and not first. We were also informed that the President had just proposed a new space agency. It had not happened yet, but that was the beginning of the considerations which led to NASA. The 49th State was just announced, Alaska, and just barely 15 years ago, jets were beginning to cross the ocean. I believe the Comet was the first one to cross the ocean. That seems like a long time ago when you look at the headlines.

In this 15-year period we completely finished the Apollo program and 12 men have trod on the moon, with all that that indicates and all of the benefits derived from that in the scientific arena.

However, looking at events, we see that the airline business is continuing to grow very rapidly. Nothing was said in the headlines 15 years ago about communications satellites because there were no communications satellites 15 years ago. There was not even a COMSAT Corp. In fact, I had the experience of trying to sell the idea of a synchronous communications satellite and everybody thought I was a little bit off my rocker. As it turned out, my predictions were, as usual, conservative as far is the future is concerned.

Now we have living color transmission by satellite from China and all the world watched President Nixon's historic trip to China.

What about the dream of flight? This is a good one to consider, because flight started, airplane flight, in 1903 at Kitty Hawk, with the Wright Brothers. In 1927 we had the first New York-Paris flight and Col. Charles Lindberg won a prize of $25,000 for the feat. I can remember—I was 8 years old at the time—waiting in a parade route to see Charles Lindberg, who was a national hero. But even at that time, most people thought airplane flight was a stunt. Everybody hed the air circus—I lived on Long Island—

out at Mineola Field, and there were air acrobatics and so forth. So in a period of 24 years, we still had not realized the real benefits of airplanes. But it was a short time later, only 7 years later, that the first DC–3 appeared, which absolutely revolutionized air travel.

What does airplane travel look like today?

First, the scheduled airlines carried 450 million passengers last year—that is almost unbelievable, but almost everybody travels by air nowadays. Thirty million of these passengers traveled overseas.

Just beginning is the air cargo industry—8 billion ton-miles of air cargo. We will have more to say about that later.

Aviation's Impact On Balance Of Trade

Aviation is now an $18 billion industry in the United States, and it has a very big impact on our balance of trade, because of that $18 billion, $3 billion is in exports. The balance of trade has moved from a $7 billion surplus to a $7 billion deficit this past year. It would have been about $10 billion if we had not had the export market of the aircraft industry. Also, 750,000 jobs are now a result of this industry.

So aviation is a going business, but on the other hand, from 1903 to 1973, 70 years, is a long time. But we certainly could not have projected in 1903 the kind of airline traffic that we have in this day and age.

Now, let's take a look at the future of the aircraft industry. There is no question about the demand. Business forecasts for the airline industry have projected a demand which is going to increase very sharply, as you see. A growth of something like a factor of four from now until 1985 is anticipated and the cumulative dollar volume is expected to be something like $100 to $150 billion in aircraft manufacturing alone. That 'arge dollar volume.

Barriers To Aviation Growth

On the other hand, if we do not do something about them, there are very fundamental barriers to this growth. The first barrier, as you well know is the noise barrier. People are getting annoyed about the noise that they hear if they live in cities, or even if they live out in the remote areas. Noise is a constant complaint. We have to do something to reduce that noise.

Congestion is a problem to all those who travel by the airlines. Congestion in the air, particularly in bad weather; congestion on the ground, waiting to take off; and then, of course, congestion in the terminal, probably mostly waiting for your bags.

Another very big barrier is the development cost. We can plot a curve showing the development cost of airplanes as a function of the time particular airplanes were introduced. We start with the DC–3, which had a very low development cost, something like $300,000, which is almost impossible to believe. But the last plane built, the DC–10, cost about $1.5 billion. So it is a new kind of ball game in the aviation industry these days and we have to do something about those development costs, if we can.

Foreigners have also observed the fact that a $100 to $150 billion market is possible in 1985 and the foreign competition is growing very rapidly. We notice this in all phases of the aviation business, but particularly in the supersonic transports. Both the Soviets and the Europeans, as you know, have developed a commercially viable—at least that is their claim—supersonic transport.

Reduced Environmental Impact

So what are we going to do about these barriers?

First, I am not going to dwell on the envi- ental impact. We have made huge strides in

the last 5 or 6 years. The DC–10, for example, already represents a 10-fold decrease in the noise that aircraft of this size emit. We expect to get a similar reduction for some older jet aircraft through retrofit programs—the new front fans and the treated nacelles. By 1985 we should gain another factor of five in noise reduction. Basically, the noise, the annoyance part of the noise, will be confined to the terminal area. Flyover noise will be below the background noise unless you happen to be on the airport.

Airport Congestion

The other factor that we mentioned was congestion. We can make a big inroad in that by automating much of the traffic and by providing all-weather operation. We can have a navigation system which brings the airplanes in properly, one behind the other, on dual landing strips and we can shrink the distance between the aircraft. We can accurately control the flight path which helps reduce the noise and also helps relieve the congestion.

The systems that do this very likely will be completely automated. You can say, well, that is risky and it will take a while for passengers to get used to that, but in any event, it will be pilot-supervised so if there are any emergencies, the pilot can immediately take over.

One other aspect is, of course, the automated taxi control on the ground, to get the plane off the strip in a hurry and to the gate. It goes without saying that we need another series of automatic controls for the baggage handling and also for ground transportation, which is a major problem at the present time.

Short Haul Aircraft Capabilities

With the new capabilities developing in short haul aircraft, we can see potential impacts on [illegible]wth of cities. For example, if you look

at Washington, D.C., around 1864, you can see the area of the city was very limited; it did not even include Georgetown. A 30-minute ride was confined to the boundaries of what is today the downtown business district.

In 1964, with the advent of automobiles and freeways, that boundary moved out as far as the beltway, a distance of about 10 miles from the city center. You can get from the beltway into Washington in 30 minutes, assuming there is reasonable traffic. It does change a little bit when there is heavy traffic. But you can see the potential for 1985. If we have a rapid means of transportation, we can then reduce some of the impact of urban sprawl and people can live in real suburban areas or, if you like, country areas —Reston, and Columbia-type new developments will appear.

We expect this will happen to a degree with the advent of the VTOL and V/STOL aircraft which are being researched at the present time at NASA. VTOL aircraft, vertical takeoff and landing aircraft, could easily move you from Reston or any of those other outlying communities up to 75 miles away into Washington, with an appropriate landing spot with traffic-control regulation, in 30 minutes.

Air Cargo Systems

Those of you that have been involved in the air cargo industry know that it is beginning to be one of those so-called growth industries at the present time. The growth is extremely rapid in the air cargo business, and billions of ton miles are forecast. But maybe the revenues would be more interesting to you. Today there are about $1.6 billion a year in revenues from air cargo. We project by 1985 something in the order of $14 billion per year in this area. To do this, we have to work on better automation in the handling of cargo. We have to get it from the trains or the trucks very quickly; and packaged, auto- handling, of course, will probably be the

way to do that. In any event, with automation in the handling and the transferral, and with the development of compatible aircraft, we think that the $14-billion-a-year estimate is reasonable for 1985.

Air Travel To Increase

Also, the increased air travel will tend to shrink the world. It already has with jet travel. But we expect in the 1985 period not only tourism but resource development, trade, and diplomatic relations will be much more important with more nations than in the past.

One thing we ought to focus on in the next period of time is the Pacific. Now, Japan, Australia, and the United States do most of the trading, but there will be a growth in all nations surrounding that area, and it is a large ocean. It is double the size of the Atlantic, but air travel will greatly shrink that ocean.

Just a reminder of what can be done with air travel, the present subsonic jets can get you from New York to Chicago in 1½ hours. This will be reduced some by transonic jets—that is, the jets using the supercritical wings. On the other hand, look at the flight from New York to Moscow. With a future supersonic jet, that trip can be reduced to the same 1½ hours now required from New York to Chicago. With a hypersonic jet, which we will be thinking about in 1985 and maybe other nations will have developed, we can get from Washington to Peking in 1½ hours.

You might know that from Washington to Peking at the present time is something in the order of 21 hours. That happens to be just about what it took in the 1940's to go from Washington to Los Angeles. I happen to have made that trip, but not in 21 hours; it took me 24½ hours in 1945.

Hydrogen-Fueled Aircraft

So much for air travel. But there is one cross-correlation between air travel and the space agency.

We are beginning to see the real future for hydrogen-fueled aircraft. Hydrogen has a much higher energy content per pound than JP fuels, and for very large airplanes and long ranges, hydrogen-fueled aircraft have a real potential. The main problem, of course, is the cost. If you look at the JP cost, though, because of lots of things we all know about, it is going to increase gradually as time goes on. Hydrogen costs, on the other hand, will decrease particularly as nuclear-breeder reactors come into being. Hydrogen could very easily be a byproduct of the breeder reactor by using the reactor in the offpeak hours. Reactors have to be on all the time, but you do not use the energy all the time; so it could spend its idle hours making hydrogen. If that is the case, the cost of hydrogen is expected to decrease as indicated. There could be a crossover point in costs somewhere around 1985. Hydrogen has a lot of fringe benefits, also. The environment problem is minimized because the principal byproduct of hydrogen burning is water. There is only one and it is water. I suppose we could get too much water in the atmosphere and that could have an impact on our environment.

As far as energy consumption is concerned, of course, JP fuel does not contain as much energy per pound as hydrogen. JP fueled aircraft, therefore, must be heavier to go the same distance, so we expect less energy consumption in the case of hydrogen aircraft than in the case of the JP aircraft.

Well, that is a kind of quick snapshot of what is happening or going to happen in the aircraft industry.

If we can recapitulate: in 1903, the first flight; in 1927, we were still asking, what good is it? What good is aviation, and so on. I can remember the New York Times, in the early 1930's, speculating as to whether aircraft travel would ever be economically viable. I wish I could have pulled out that article. I was 12 years old at the time, so that must have been 1931. It was asking what good it was, and 7 years later we [illegible]e DC–3 and the aviation age truly began.

Conquest Of Space Begins

We can now ask the same question about the conquest of space. In 1962, the first U.S. astronaut was orbited. In 1972, 10 years later, we had landed 12 men on the moon, a very spectacularly successful program. But people are still asking, "What good is it? What does it do for me now? I know people have landed on the moon, but how has it helped me?"

Well, I am going to make an attempt to try to answer such questions. Remember, space flight is only 15 years old and 55 years behind the aviation industry. So it is much easier to project ahead in the aviation industry than it is in the space industry. But nevertheless, 15 years is not that far into the future, so let's go.

Reasons For Exploration Of Space

The first question you might ask is why do you want to go into space—why do you want to orbit? Most of you know the answer today. Basically, it is that with only three satellites placed not too far out, maybe 8,000 miles out, you can cover the entire globe. With synchronous communication satellites, which are much farther out, you not only can cover the entire globe, but they are standing still with respect to the earth. You will see the impact of that geometrical factor later.

The other advantage is that, by putting a satellite in a near polar low or high orbit, the earth rotates underneath the satellite as it goes around, giving really global coverage over periods of time with a single satellite. There is nothing to slow the satellite down and the farther we go with electronic developments, the longer we can make these satellites last. So it is almost as if they were platforms sweeping out a portion of the globe every 90 minutes.

These are fundamental factors of satellite potential. Now, we will move to something you are also familiar with, and that is another factor in-
n exploiting this potential.

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Space Shuttle, Key To Economical Satellites

If we are going to have lots of economical satellites in orbit, we are going to launch them a little differently than we have in the past. The largest booster is the Saturn V stack, and it is pretty expensive. We do not see how we can use the Saturn V at the present time for any economically viable enterprise, although it has great potential for further space exploration. So we decided the way we had to move is to the DC–3 type of operation. The DC–3 was really the beginning of the aviation age, and the Shuttle is the key to the DC–3 type of operation in 1985 or actually, earlier. It has the potential for heavy payloads and all kinds of other potentials such as highly reliable, reusable payloads, payloads that you can refurbish, keep resupplying; and it also offers quick reaction capability. None of those are available with our current vehicles. So the Shuttle will really be the big advance in the space age, and it will not be very long before people will quit asking the question, what good is it?

Space Communications

Some of the aspects of space you are already familiar with, so I am going to try to extrapolate those first. The easiest one to extrapolate is space communications, because we already have a going business in space communications. We have 65 TV ground stations already operating in 49 countries. Space communications now primarily support overseas communications.

The revenue is $260 million per year to the Intelsat Organization, and 38 percent of that comes to the United States through the COMSAT Corp. There are now 36,000 two-way voice channels overseas, compared to 8,500 on cable. This is a factor of four increase in just about the last 5 years. The number of voice channels has increased and if any of you have tried overseas

phone calls, you know that you can get through right now as opposed to waiting up to several hours as you did in the days of cable communications.

Potential Of Domestic Satellites

You can get a feeling for the potential of the newly instituted domestic satellites by looking at the current revenue of the telephone, radio, and TV business, something like $18 billion per year. And we have seven companies now vying to be the first one to put up a domestic satellite and the chances are all seven will be doing this.

Well, you see, when we start increasing the size of the communication voice channels, it is going to have a huge impact on our society. We are going to be using the telephone for discussing almost anything. It is also an important fact to point out that when you have a satellite, a long-distance toll to Richmond costs the same as a long-distance toll to Peking. The same satellite may be used for either call.

New Dimensions In Education

Better communications will be used in a lot of different ways. Education is the first application that we can see very clearly, because we need, even in the high schools, access to large-scale digital computers.

We are moving into the computer age, also one of the spinoffs of the space program.

High schools, universities, all educational institutions, will have access to a regional computer.

Now why do you want access to a computer? Well, computer-aided instruction is the coming thing. This is the quickest way to learn if we can afford to build the system, and by 1985, we think we can.

Today, education in remote regions is a . Those of you that are involved in the

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affairs in the Rocky Mountain States know that we have an experiment scheduled for 1974 with the ATS-F, bringing education to some of the remote parts of the Rocky Mountains and also to Alaska. This has huge potential for other parts of the world as well. But even in our country, we expect this to have a very large impact. By 1985, the quality of education should no longer depend on the locale where students happen to live.

Another aspect which is important to remember is that libraries and universities can be tied together. Libraries are a very big expense to universities and I speak with some experience. Yet even at the University of Utah, we did not have the coverage, anywhere near the coverage that they have at the Harvard University library or the Library of Congress and of course, not even these institutions can be the equivalent of all the libraries in Europe and throughout the world. With the use of micrographics which can copy down most of the books in the world; all schools and universities can have access to these same libraries.

Transportation

We ought to remind ourselves about the potential of satellites to improve transportation, particularly air and marine transportation. We were asked by the Maritime Administration to provide a communications and navigation satellite which would help them route their traffic efficiently. They have two problems. One is weather and the other one is arriving at their destinations on time. You may wonder why that would be important, but they have all of the people on the shore waiting for them if they are late. They have to pay top wages to these people, and there is a great waste at the present time. In fact, the biggest cost of ocean shipping nowadays is on the shore, handling the cargo at each end of the trip.

, with economic real-time routing through

communication and navigation satellites, with the business of collision avoidance during bad weather and with natural hazard location, and search and rescue, we can make a big impact on the marine industry.

All that has been said about the maritime industry is also true of the aircraft industry. We do not worry about the aviation industry right now because we seem to be the leaders of the world. On the other hand, we are not the leaders of the world in the maritime industry. Our revenues are something like $2.6 billion per year, whereas the total volume of worldwide shipping is about 20 times that and we are worried about the dwindling fraction that the United States has of the maritime revenues. A sobering thought should be pointed out: that is that even though our maritime revenues are small, our total export-imports are large, $42 billion per year.

We have another point which is not mentioned very much, but is also an important aspect of our every day lives.

Global Rescue Locator

Something like 3,750 people a year from the United States find themselves in distress situations and need to be rescued. This is about one-tenth the total of the world distress situations. I am speaking about downed aircraft as well as marine incidents. Something like 45,000 people a year are in distress situations and need to be rescued in some way or another. (I noticed yesterday also that NASA has been working on a cheaper, more visible life raft.) We could have a search and rescue system which would be operated using a satellite. This would be a very inexpensive satellite, no real difficulty in the technology, a very small pocket-sized radio aboard the life raft, for example, would allow almost instant pickup and location of the signals from the life raft.

Access To Remote Areas

Another area which is just beginning to be recognized is that we can have through these communications and navigation satellites remote access to expeditions of various kinds—scientists or explorers. We can hook these expeditions up to computation centers, libraries, weather centers, and if there are medical problems, we can hook them up to diagnosis centers and, of course, receive emergency aid. Now, I think it is worthwhile in passing to mention that Jacques Cousteau took advantage of the access to a communications satellite which NASA had placed in orbit, not for his purpose, but which happened to be there, in his latest exploration trip to the Antarctic. He ran into trouble when his propeller shaft was broken and we were not only able to help him but to guide him through a field of icebergs to his destination in South America.

Space Age Sensors—Aid To Preventive Medicine

A large fraction of our GNP goes into the solution of medical problems. So the medical industry is substantial from an economic view. But what is more important, perhaps, is that we have a potential here in communications satellites and improved sensors to improve the health of the Nation. A fairly large effort is now being mounted in this country toward preventive medicine, preventing diseases from occurring before they occur. Currently, a large fraction of our revenue goes into making sick people well. What we want is the benefit from a fraction of the revenue going to preventing people from becoming sick.

So one of the ways to make a big impact is by doing a better job at preventive medicine, by having home physicals, for example. Most of the people in the United States just do not get the physicals and certainly not in the depth that are necessary to protect them from some of the very serious malignant diseases. So we

can conceive of self-administered sensors by simply putting on a jacket with the sensors in it, hooking up to the comunication line, which then goes through whatever mechanism necessary to a central diagnostic center. All of the sensor readings are fed into a computer, and a technician reads out all the essential elements of the physical. You can make that as sophisticated as you want, depending on the sophistication of the jacket which the man rents for his physical. This approach would be a lot cheaper and a lot less trouble. So we think this aid to preventive medicine can have a big impact on the general health of the country.

Space Sensors—In Rapid Diagnosis

We can also have an impact on the diagnostic problems if we get sick or we have a pain and we do not know what is causing it. It would be very helpful to plug in, again, these same sensors, transmit readings to either a public or a private medical center, and have these symptoms diagnosed and get instant readings back. This again will save lives in terms of accurate and immediate diagnosis and particularly in rural areas, where there just is not access to a physician, let alone a specialist.

Space Sensors—In Emergency Medical Care

We can see also the potential for emergency situations. Perhaps the best-known example of an emergency is a coronary. It is estimated by the medical world these days that 50 percent of those who die of a coronary could be saved if they had been transported to an intensive care unit in time. Fifty percent is a large number. That is today. If we had some mechanism for transmitting to the emergency area instantly what these intensive care procedures should be, and an elec-
ogram is an important aspect of that,

we very likely could save a large fraction of those 50 percent that die.

The same is true of accidents of all kinds; and if we have VTOL transportation, we can move patients to the appropriate hospital in time. This VTOL transportation via helicopter is already almost routine for many emergency hospitals throughout the country.

Weather Satellites

Now we are talking primarily about weather satellites which are also fairly well known and, therefore, easy to predict in the future.

Here is what we have today. We have emergency weather stations at Miami Hurricane Center, Kansas City Tornado Center, and we have a regional weather center in San Francisco, all receiving data from the weather satellite. These satellites are in low altitude orbits and take readings every 2 hours or so on the weather they pass over.

In addition to that, though, this year we expect to put up a synchronous meteorological satellite, which will continuously observe the weather for one part of the globe. Early warnings of storms will be available, and in real time the progress of the storm will be tracked.

Global Weather Network

With the weather satellites, it is likely that we will have a global weather network—not just for disasters and emergencies, but for accurate, long-term forecasts. Long-term forecast means, say 2 weeks.

We do well to get 1- or 2-day forecasts now, but by knowing what the total weather is like throughout the world, accurate, long-term forecasts will be routine. There is a very intensive program in the United States, of which NASA is a part, to measure intensively this weather—not mean just photographing the clouds. I

mean measurements of the atmosphere itself, temperature versus depth in the atmosphere, and also the condition of the oceans and the temperature of lakes—all of which have an impact on the global weather. You can see the potential of accurate 2-week forecasts to economics. The agriculture and forestry and fishing industries will all benefit from longer forecasts of the weather. The construction industry is impacted a great deal of the time because of the weather, and the transportation industry, as we all know, is also vitally affected by the weather.

It is not possible to say at this time how much these industries would be affected by the 2-week forecast but there was a study made by the University of Wisconsin for the State of Wisconsin, in which they estimated that the value of improved forecasts in direct cost reduction to farmers which would be realized in the next 10 years, largely as a result of improved satellite data, would be about $20 to $35 million a year on just the crops of hay alone. Such a savings alone each year in one State gives you some idea of the potential to be had in the future from a global weather network and improved long-range forecasts.

There is also potential for weather modification. I do not have to tell most of you gentlemen how much of an impact that would have, since most of you are involved in conservation of water resources and so on, but it certainly has a big impact on the water resources, on the crop protection from hail. Of course, we also need to be able to have some dependable impact on the weather near airports.

Earth Resources Satellite

Perhaps more importantly is the overall problem of water in this country. This is what we can do today. By taking an ERTS picture of an entire watershed, we can get a very good idea of what the water runoff is and the water rain- and we know where to collect that water.

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We know that there is forest land in an area, grassland, and a big part of a watershed in a particular area.

Putting this all together plus knowing the rainfall, we can make accurate predictions of available water resources.

Water Resources Management

In the future we may have a national water resources management program. I should not say we may have, I should say we must have, because right now, we are using more than 300 billion gallons of precipitation every day. We are using about a third of the total rainfall for agricultural, industrial, and domestic purposes. We will have to use two-thirds of the water supply in something like 12 years. So this means we have to know how to manage our water resources. There are some political problems on that. I happened to live in Utah for 7 years, and I know some of the difficulties. Who gets whose water is a big problem. But nevertheless, we will have the resources to actually know where the water is, where it is going to be, and to a slight degree, we can even control where it falls. There might be some political disputes about that one, but on the average, if we take into acount national, local, and State needs, there will be a major water resources management program.

Land Resources Management

Land is not scarce in the United States, but it is becoming a major national resource, and we have to take care of it. We can do this today. Using ERTS photography and computer processing of the data, we can prepare a map which puts every aspect of land use in a special color. We have already made such a map for Rhode

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The important thing about this map is that this was all done in about 40 man-hours, what normally would have taken about 16,000 man-hours, from the normal aircraft flight data. Forty hours is a pretty short time, and maybe an additional important point to make is that this was done on current data, ERTS data, that we are getting every 18 days. At the time the ERTS map was prepared, the most important land use map for the area was 2 years old.

So looking at the future, then, we can visualize in this country a national, local, and State land use management control center in which daily or at least weekly, we know how land is being put to use. We will thus be able to optimize this very critical national resource.

Air And Water Pollution

Now, on a different subject. Pollution has been talked about a great deal in recent times, and it is an economic factor as well as an annoyance factor. A total of $6 billion per year is estimated to be the impact on human health; and $10 billion a year on property and materials in the United States, just due to air pollution alone.

Perhaps more important for a lot of us, or just as important, is the annoyance factor. With all these chemicals in terms of millions of tons going into the atmosphere per year, it is causing serious concern. We think we ought to be able to do something about it.

And another problem is water pollution. It is in the same category. The problem includes but is not limited to just oil spills; sewage also goes into our waters, and many of our streams are polluted. We estimate that $350 million a year is lost in recreation alone. We know that the shellfish industry is in danger. Already 20 percent of our U.S. shellfish beds have been closed.

This is the situation we are in. We are beginning to detect remotely some of this pollution. C mple is from an ERTS picture. This

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particular one is an acid dump. Somebody went out into the ocean off Sandy Hook and dumped acid, which shows up very clearly. Coincidentally, there is a sewage and garbage dump that also shows up very well.

We can enhance almost any aspect of the ERTS pictures we are looking for. We can enhance the agriculture, land use, and we can enhance the water pollution and so on.

Looking into the future, it is easy to visualize that we at least need a national environmental monitoring system, and perhaps if we can work out the international arrangements, a truly global environmental quality monitoring system—for air, water, to some extent land, and space. Air and water has to be done that way because when I pollute the air, I pollute somebody's air in the next State; or if in Europe, for example, the next country. If I pollute the water, I can easily pollute the next country's water. In fact, I can pollute the whole ocean. So ultimately, we have to arrive at a global pollution monitoring system.

Land pollution is not so general, but space is. We do have to worry about space garbage and what we do with it. So it is conceivable and likely that we will have a control center watching on a continuous basis the world's waters and atmosphere, and this will have to be, then, tied in with the national and the local people who are the enforcement entities.

Global Crop Management

Another aspect is the business of global crop management. We can, with ERTS, measure quite accurately the approximate ground area, at least, of the grain crops of the world. This can have an enormous impact. You can certainly pick out things like wheat, rice, and corn. We can measure the health of the wheat, rice, or corn in terms of disease, insects, and weeds.

The Agricultural Research Service has estimated that 33 percent of the U.S. crop is lost due to these factors. Well, with a U.S. industry

of $25 billion a year and a world industry of about six times that, you can see that just a small contribution to the solution of the world's agricultural problems could easily pay for the entire space program.

Monitoring Global Disasters

Another area which we are just beginning to visualize is looking at disasters remotely—i.e. global disasters. We took an aircraft picture of Managua, Nicaragua, just after the earthquake. We were asked to fly over the area by the Nicaraguan Government. In the middle of the photo it is very easy to see that the center of the city was completely demolished. The preliminary pictures, when we looked at them, indicated that maybe only 10 percent of the city was destroyed. Looking at it more carefully on a detailed map, it became evident that almost 80 percent of that city was severely damaged by the earthquake. We were able to help them, to some degree, route relief trucks into the not completely demolished areas, and we can see a lot of potential for this kind of disaster alert center.

Disaster Alerts

It is very possible that nationally or maybe internationally, we will have a disaster alert and relief control center in which we monitor the world's disasters—not just earthquakes, but hurricanes, tornados, any kind of natural or man-made disaster. We will know what happens instantly with our global system and be able to communicate with the appropriate people to take the necessary action.

Skylab Experiments

Now, we can move to an entirely different aspect of space. Skylab is going to fly in mid-

May of this year. I have only picked out one of the experiments on Skylab to discuss and that is *biological space processing*. It is hard to understand what I am saying unless you have watched people separate viruses or bacteria for medicine. I have been actively involved with the president of the company that I was chief executive of for 6 years. We did make viral antibodies for commercial use, and the vaccine production is a tremendous chore. You have to go through all kinds of separation techniques to get the useful bugs out of the bad bugs, so to speak. Vaccines particularly have this problem. And one of the chief hindrances is the business of convection and sedimentation caused by gravity.

The vaccines are usually in solution of some kind and you try to separate them out by differences in density, which are not very great, or by differences in electrical properties—electrophoresis, we call it. Aminoelectrophoresis is one aspect of it. As we have no convection in the zero gravity environment of space, it can make a big impact on this industry. The vaccine industry projected to the year 2000, is $12 billion a year. Even if we used a 10th of that, we could have a regular vaccine production enterprise and make the Shuttle pay for itself in just a year or two. This is almost certain to come about, I would say, providing experiments in Skylab show that convection indeed can be eliminated for viral production.

Of course, we use viruses for other things besides vaccines. We have viral insecticide and we project a market in the year 2000 of $2 billion for that. So the potential here is very large for doing biological space processing. The same is true in 8 or 10 different areas of manufacturing which we are going to experiment with in the Skylab.

Another potential experiment is something that this committee has spent a lot of time thinking about, the use of *solar energy*. Solar energy is essentially pollution-free. The only pollution it produces is a little bit of thermal pollution around the place where the energy is collected and converted for use. If we did it in space, we

could even get rid of that problem.

A 100 by 100 mile array of solar cells located in a state where there is plenty of sunshine, would supply all of the U.S. electrical needs in 1985, and we believe can be cost-competitive with other means of generating energy. I do not mean to say we will have such an array by 1985. We will have smaller arrays by then, either on an experimental or pilot basis, which will show what you can do with solar energy.

International Space Laboratory

Another potential is an international space laboratory. I say international because of the interest by Europe in a Space Shuttle laboratory, particularly the part of it that we call the Sortie laboratory, which is the laboratory that can be taken up by the Shuttle. It can house 12 scientists or viral manufacturing experts or whatever, and they can stay in orbit for a few weeks. The reason the Europeans are interested in this is that they can see a great potential in having their own people work in space. As a matter of fact, they have agreed to contribute $300 million, which is the total cost of development of the Sortie lab. They have given it the name "Spacelab."

Large Space Telescope

Moving on to another facet of things that we are working very hard on, we have the Large Space Telescope (LST). The Large Space Telescope is to be carried to orbit and serviced by the Shuttle. We expect we will be able to see 100 times better than the best ground telescope with this LST. This is important from a scientific point of view, but it may also be important from a practical point of view to know what the energy processes are in these strange stars—quasars, pulsars, neutron stars, and black holes, which we have not seen, but which we are beginning to see the effects of.

Understanding matter generally and the overall recycling processes of matter in the universe will be important for us. With the aid of the LST, we will probably have a better understanding of these phenomena in 1985.

In general, the structure and the evolution of the universe will be studied with this Large Space Telescope which we anticipate will be flown as one of the early missions on the Shuttle.

Similarities Between Earth And Mars

Now, looking out away from the galaxies, of which there are many, and looking at just our nearest neighbor, Mars, we were amazed to find that there appears to be a dry riverbed on Mars that looks almost identical to one in East Africa, the Niger River. Mars is beginning to look more and more Earth-like as we learn more. It rotates about the same rate as Earth; it has four seasons like Earth.

As we go on, there are very great similarities, even clouds—not to the extent that we have on Earth, but water clouds have been televised by Mariner 9.

International Lunar Expedition

Another possibility, an almost certainty for 1985, is a return to the Moon. I say almost certainly, not because we have plans under way to do this but because it is very likely that the Soviet Union does, and it is very likely that when we go back, they will be there.

The Moon has great potential for an international lunar expedition with the Soviets and with the Europeans. Europeans are very good at building instruments and telescopes. They very well might build, say, the observatory. The United States might build the transportation system, and the Soviets the lunar rover vehicle. They are getting more and more proficient in [illegible]ca. It would, of course, not have to divide

that way, but nevertheless, it is conceivable that when we get around to establishing a lunar base, it will be an international endeavor rather than solely a United States or Soviet endeavor, partially because of the large costs that are involved—not larger than the Apollo program, but still large compared to NASA's budget as presently anticipated.

Experiments On Lunar Surface

A lunar surface base could serve international groups with common laboratories, life support, and power systems, while providing separate crew modules. What can you do from the lunar base? Perhaps the most spectacular photograph we have is one taken from a lunar-based telescope. It is an ultraviolet picture of the Earth. The Earth is in partial shadow. It is a half Earth taken in ultraviolet light. It shows the oxygen layers way out in space and some strange contrails, so to speak, due to the magnetic field of the Earth. Several were anticipated, but there is another one intersecting the main magnetic contrail which nobody has yet explained. So it is important to continually observe Earth, and the Moon is a good platform for this.

I am sure you have seen the more familiar picture of Earth rising over the lunar landscape. This has more psychological impact, and probably for good or for bad, this was the introduction of the ecological age. There were a lot of ecologists around before this picture was taken, but when we began to see how finite our Earth was and how beautiful, we decided we had better start taking care of it. So this made graphic or visible the overall problem of how we need to take care of our home, the planet Earth.

Stars And Galaxies

Moving back into the stars and galaxies, it is hard to know where to begin with stars and galaxies, because there are 100 billion stars in [illegible]laxy. One hundred billion stars. That is

hard to conceive. But in addition, there are 100 billion galaxies in the universe. You multiply those two numbers and you get how many stars there are.

So if you like, we have about 30 galaxies for every man, woman, and child living on this Earth today. It is important to study the galaxies. There are people living out there. Just what we would learn from them, of course, has to be studied further, but someday, we may very well be communicating with people in other solar systems.

Moving down from our own Milky Way galaxy, the Sun is just a small piece of that galaxy way out on the outside. We had hoped we would be the center of our own galaxy and we were not even that—not even the center of the galaxy or the universe. Our Sun is just a little mediocre star out there on the edge of the Milky Way galaxy. But the Sun is important to us, because it is the center of our solar system.

The Solar System

The solar system, of course, is very important to study because by learning what the other planets are like, we learn about the evolution of our own planet. Studying the Sun, of course, is absolutely indispensable, because it is the source of all energy here on Earth. So we cannot give up our study of the Sun.

Projections Are Conservative

As soon as I got this all put together, I realized very quickly that I had been too conservative and it was very clear that the scientist in me had gotten the upper hand. The possibilities that I have described here require no new technology. They involve technology that we know about today. Lots more work is going to be done, though, on projections, but for this briefing, technical breakthroughs are projected. The

principal changes I have described have to do with politics and economics and these are things that are beyond our control, but I have made a businessman's attempt to try to project those.

If I would have projected the real future in 1985, it would have been a good bit farther out than what you have seen, and it would probably have been closer to the mark.

One other thought that I am sure ran through your minds as we went through this forecast. As you know, NASA is called the space agency, but in a broader sense, we could be called an environmental agency. It is not just that space is our environment, but it is rather that, as you have seen, virtually everything we do, manned or unmanned, science or applications, helps in some practical way to improve the environment of our planet and helps us understand the forces that affect it. Perhaps that is our essential task, to study and understand the Earth and its environment. Thank you.

ERIC 65-400